1995

Structure and tectonics of the Gunnedah Basin, N.S.W: implications for stratigraphy, sedimentation and coal resources, with emphasis on the Upper Black Jack group

N. Z Tadros

University of Wollongong

University of Wollongong *Year* 1995

Structure and tectonics of the Gunnedah Basin, N.S.W: implications for stratigraphy, sedimentation and coal resources, with emphasis on the Upper Black Jack group

N. Z Tadros
University of Wollongong

Please see print copy for image

STRUCTURE AND TECTONICS OF THE GUNNEDAH BASIN, N.S.W. - IMPLICATIONS FOR STRATIGRAPHY, SEDIMENTATION AND COAL RESOURCES, WITH EMPHASIS ON THE UPPER BLACK JACK GROUP

A thesis submitted in fulfilment of the
requirements for the award of the degree of

Doctor of Philosophy

from

UNIVERSITY OF WOLLONGONG

by

N. (Victor) Z. Tadros
B. Sc. (Hons.) Geol and App. Geol. (Ain Shams Uni., Cairo)

Department of Geology
1995

Frontispiece:
Coloured image of residual Bouguer gravity anomalies of the Gunnedah and Sydney Basins and southern part of the Bowen Basin with wavelengths less than 120 km. The red colour equals high values and the blue represents the low values. The image shows the prominent Meandarra Gravity Ridge which runs along the axis of the basins. The ridge appears to be transversely displaced along north-east-oriented lineaments/trends. The image is provided by R.N. Walker of Geoimage Pty Ltd using data from the Australian National Gravity Data Base, established by the Australian Geological Survey Organisation (then the Bureau of Mineral Resources) and contains data from the New South Wales Department of Mineral Resources. The image has been published as a front cover photo in Tadros (1993b). See text in chapters 3, 4 and 5 this thesis.

ABSTRACT

The Gunnedah Basin has long been considered a foreland basin. This study found that the basin consists of several linearly arranged troughs defined by bounding longitudinal and transverse ridges and highs. These features, together with the distribution and type of the Early Permian sedimentary basin fill and the associated volcanic rocks, strongly indicate that the basin's origin is consistent with volcanic rift models. The Meandarra Gravity Ridge, which represents a significant zone of inhomogeneity in the upper crust caused by deep-seated dense mafic intrusions, provided a key tool for resolving the early history of basin development. The ridge is laterally displaced by low gravity transverse trends representing transfer structures which were active during rifting and thus bound rift compartments of varying size and subsequent thermal subsidence histories.

There is a striking correspondence between the high gravity anomalies and the trough areas which contain the thickest sedimentary pile (and hence maximum subsidence), and also between the low gravity transverse trends and the mapped transverse structural highs in the basin. These relationships, together with the linear arrangement of the troughs, enabled prediction of basement structure within areas of little or no borehole control, provided the basis for subdivision of the Mullaley and Gilgandra Sub-basins into structural subunits, and enabled prediction of basement faults which have little or no surface expression.

During the Early Permian, the volcanic rift-related transverse and longitudinal structures were the main source of sediment and effectively controlled and confined sedimentation to the trough areas (overlying the half-grabens). Thermal relaxation followed in the mid-Permian and caused basin-wide subsidence, widespread marine transgression and deposition of the Porcupine and Watermark Formations, but the rate of subsidence in the trough areas was still significantly higher.

The change to foreland tectonics in the mid-Permian provided a new source of sediment from the overthrusted New England Fold Belt. Tectonic loading in the Late Permian caused subsidence of the eastern half of the basin and establishment of lacustrine conditions. Structural readjustment along the eastern edge of the cratonic Lachlan Fold Belt caused uplift of a forebulge and shedding of quartzose detritus to the Western Fluvial System which infilled the lake and expanded through the axial drainage via southwest-flowing tributaries. Fluvial incision of the underlying Western Fluvial and Lacustrine Systems and sediment intermixing are evident in the main channel complex. Influx of coarse detritus from the New England Fold Belt and westward movement of the basin axis caused south-westward migration of the axial drainage complex.

Widespread silicic volcanism in the New England Fold Belt region contributed large amounts of pyroclastic detritus to the basin-fill. A major phase of lateral compression and thrusting of the New England Fold Belt onto the craton caused structural readjustment and uplift, particularly in the north, and ended Permian deposition in the basin.

Although foreland loading of the thrust belt was the dominant cause of subsidence during deposition of the Late Permian Black Jack Group and the Triassic Digby and Napperby Formations, the inherent volcanic rift-related basement structural elements had a significant effect by varying subsidence rates in the different basement compartments and consequently on development, distribution and geometry of depositional systems, their component facies and peat accumulation, as well as on emplacement and distribution of igneous intrusions and extrusions in the basin.

In the Late Permian and Triassic, longitudinal structures were periodically reactivated as thrust faults resulting in uplift and erosion of much of the upper Permian sequence particularly in the Maules Creek Sub-basin and the northern Mullaley Sub-basin.

The basement structural elements also controlled the distribution of igneous intrusions and volcanism. Late Carboniferous to Early Permian eruptions followed transfer faults and floored the developing Gunnedah Basin with basalt, while silicic volcanism appears to have developed parallel to the basin margins along longitudinal extension/detachment faults. Reactivated major transfer faults provided pathways for Jurassic and Tertiary phases of igneous intrusions and extrusions.

Recognition and mapping of basement structural elements and understanding of the basin's tectonic history highlighted the interrelationship between basin origin, tectonics and sedimentation and provided a framework for sedimentological and stratigraphic analysis and coal resource evaluation.

An hierarchial approach to genetic stratigraphic analysis has been applied to the study of the upper Black Jack Group. The analysis included definition of the geometry and distribution of genetic stratigraphic units and mapping sediment dispersion patterns within the sequence in order to develop sedimentation models and to determine the palaeogeography and tectonism expressed as basin subsidence and uplift in the source regions.

Sand body geometry of the upper Black Jack sequence emphasises the structurally controlled fluvial character, with a major axial trunk channel complex fed by easterly and westerly contributory channels.

The Hoskissons Coal and the Breeza Coal Member are regionally extensive, have tectonic and time significance and serve as genetic sequence boundaries. These seams separate genetic sequences of distinctly different depositional settings, bedding architecture, and sediment composition. The basin-wide accumulation of the Hoskissons peat represents a significant period characterised by almost total non-deposition of terrigenous clastics and marks a change in basin depositional history from predominantly deltaic and shallow marine sedimentation to fluvial and lacustrine conditions of the upper Black Jack depositional episodes. The Breeza Coal Member marks the change from the Western Depositional Episode, during which the basin fill was dominantly quartzose, derived from the Lachlan Fold Belt in the west, to the Eastern Depositional Episode when the sediment supply was from the New England Fold Belt in the east and was mainly lithic.

Four major genetic elements: the Hoskissons Peat-swamp, the Lacustrine, the Western Fluvial and the Eastern Fluvial Systems, have been recognised by their different lithology, and depositional and tectonic setting and by their palaeogeographic relationships.

The depositional systems served as mapping units with bounding surfaces for the contained genetic facies and allowed establishment and or refinement of correlations of several subregional coal seams. These seams, although not representing sequence boundaries, have time significance locally and have been used in finer subdivision within the larger genetic stratigraphic packages. Detailed lithofacies mapping of the interseam sediments provided the means to reconstruct the evolution of the upper part of the Black Jack fluvial systems, enhanced recognition of depocentres, revealed areal and stratigraphic distribution of sand bodies within the genetic units and ultimately allowed recognition of the impact of basement structures on sand distribution.

The genetically defined units provided the basis for the establishment of a new formal lithostratigraphy for the entire Permo-Triassic Gunnedah Basin sedimentary fill. In all, three groups, three subgroups, 13 formations and six members have been formally named and described in detail for the Permian section. Three formations and two members have also been formally named and described in the Triassic section. The expanded knowledge of the Gunnedah Basin sequence also allowed correlation of the stratigraphy and depositional history with those of the Sydney Basin.

The Hoskissons Coal, is the product of the Hoskissons Peat-swamp System and consists predominantly of vitrinite-poor, inertinite-rich coal with high liptinite content. Vitrinite content decreases upward in the lower section of the coal and increases upward in the upper section with a corresponding increase in the amount of disseminated and discrete mineral matter. Liptinite (mainly sporinite) content increases towards the top where alginite is also present.

The Lacustrine System displays cyclic alternation between upward-coarsening sediments of lake margin facies and organic-rich mudstone of lake basin facies.

Architectural element analysis of the Western Fluvial System indicated that the sandstone was deposited by discrete, broad, probably shallow, low sinuosity channels comparable with Models 9 and 10 of Miall (1985) for low sinuosity rivers, and the middle-upper Brownstones of Allen (1983). In vertical profile, the sequence combines features characteristic of low sinuosity rivers of the "Platt type" and the "South Saskatchewan type", or its ancient analogue - the Battery Point Formation.

Axial and tributary channel fill deposits of the Eastern Fluvial System consist mainly of volcanic-lithic conglomerate. The flood plain facies consist of carbonaceous sediments, thick stony coals and tuff .

Depositional setting had a significant influence on quality and continuity of the Hoskissons Coal. Therefore, in addition, the study included comprehensive analysis of the maceral composition of the Hoskissons Coal and applied coal facies analysis in order to understand the peat-forming environment and the factors that controlled the changes in that environment and consequently variations in coal quality and distribution. Subsidence was the major factor that controlled development of the Hoskissons peat swamp, influx of clastic sediments and consequently, coal quality and thickness. Rate of subsidence was uneven across the basin and was structurally controlled, and in part influenced by compaction of the peat or of the underlying platform of marine sediments.

Initially, shoreline sands (of the preceding upper Watermark-lower Black Jack/Arkarula Depositional Episode), in the south, protected the peat swamps from inundation by the sea and kept the water table high enough to produce vitrinite-rich plies, low in mineral matter and sulphur, at the base of the seam. The general trend of upward decrease then increase in vitrinite content of the Hoskissons Coal indicate a gradual fall and subsequent rise in the water table which ultimately "drowned" the peat and established lacustrine conditions in the eastern part of the basin. Raw and washed coal isoash trends show a dominant fluvial influence on coal quality. Geographic zonation of the SiO_2/Al_2O_3 ratios of the coal ash corresponds closely with regional trends in the associated depositional systems. SiO_2/Al_2O_3 ratios are high in the north and south-west as a result of the influence of the quartz-rich western fluvial sediments. Tectonic stability and minor influx of clay-rich sediments from the New England Fold Belt region contributed to the low to medium SiO_2/Al_2O_3 ratios in the east.

Basement structural elements were active during sedimentation and influenced subsidence, sedimentation and peat accumulation. There is a strong relationship between the Hoskissons Coal lithotype profile, quality and thickness and basement structural elements. Organic-rich mudstone formed in rapidly subsiding areas in the centre of the trough areas where, in some places, the Hoskissons Coal has been replaced by clastic sediment. Lowest rates of subsidence on the highs and ridges produced a thin seam and exposed the coal to some degradation and partial erosion.

Sand content of the underlying platform had some influence on subsidence and consequently on coal thickness and quality. Localised compaction of the peat also contributed to subsidence in the north and central eastern areas.

Coal seams above the Hoskissons Coal, were also strongly influenced by their depositional setting. Peat accumulated in interchannel areas adjacent to the axial channel complex and principal tributaries. Location of the axial channel complex was largely structurally controlled and occupied the areas of maximum basin subsidence. Moderate subsidence rates in the north tended to entrench the axial channel complex which, as a result, isolated the peat swamps in the interchannel areas and produced fewer seams that are hard to correlate. Rapid subsidence rates in the south and south-east allowed greater lateral shift through aggradation and avulsion and favoured thick widespread peat accumulation except where the swamp has been disrupted by sediment influx from nearby channels.

The comprehensive analysis of the structure and sedimentation, complemented with a study of the peat swamp environment and coal facies analysis, greatly improved understanding of the factors which controlled peat swamp development and peat formation, coal quality and distribution, seam thickness and splitting, and the nature of the mineral matter in the coal, and provided the basis for reliable seam correlations. All of these are important factors in the assessment of the basin's coal resources, which are estimated at 29 billion tonnes of potentially usable in situ coal. The Black Jack Group contains the vast majority of that resource, and nearly half of the total resource is contained in the Hoskissons seam.

The remaining coal resources are contained mainly in the six seams overlying the Hoskissons Coal, particularly in the Caroona area, except near the axial channel complex where quality deteriorates and in some cases the seam is split or replaced by fluvial channel deposits.

Exploration in the basin has concentrated on the Breeza, Caroona, West Gunnedah and Narrabri areas within the potentially economic zone of shallow (<500 metres), good quality coal in the east, where borehole spacing is between 4 and 8 kilometres or less and seam correlations are well established, allowing the coal resources to be calculated to Inferred status. The bulk of the resources of Hoskissons and the overlying seams is amenable to underground mining methods only.

ACKNOWLEDGEMENTS

This study was carried out under the supervision of Professor Brian G. Jones. I am grateful to him for his help, patience and encouragement.

Also, I wish to thank Aivars Depers of the Department of Geology, University of Wollongong for lending me a coal petrographic microscope and a point counter for several months to investigate the large number of coal samples used in this study, and for allowing me access to the core slabbing facility of the department. I also wish to thank Mrs. R. Varga who introduced me to the art of preparing polished blocks for coal petrographic analysis.

My direct involvement in the New South Wales Department of Mineral Resources' Gunnedah Basin exploration programmes between 1980 and 1987 and the work on the Gunnedah Basin Memoir between 1987 and 1993 have given me access to a very large data base and a unique opportunity to study a new basin at all phases of the investigation. In addition, The department provided logistic support and access to facilities such as computers, printers and a petrographic microscope to study thin sections of drill core samples. I acknowledge such support and wish to thank my direct supervisors and managers for their understanding.

Over the years, during the course of this study, I was stimulated and encouraged by many people, to all of whom I extend my gratitude. I make special mention of Professor Brian Jones, who guided my work and reviewed many of my publications; of Dr Erwin Scheibner, with whom I had lengthy discussions on many aspects of the tectonics of eastern Australia; and of my friend and colleague Dr Douglas Hamilton, with whom I had the pleasure to work in the field and the office, and whose interest in sedimentology and depositional analysis was infectious.

Finally, I wish to thank my wife, Therese, and my children, Margaret and Michael, who have sustained and encouraged me, generous as ever, and tolerated my incessant work on nights and weekends, and did their best to spare me from many obligations which I should have undertaken. In the final stages, Michael came to the rescue and helped in copying and collating a large part of the thesis. Foremost, Therese deserves my appreciation not only for tolerating it all, but also for typing the first draft of the thesis. I am greatly indebted to her.

DECLARATION

Except where otherwise acknowledged, this thesis, including all figures, represents the author's original research which has not previously been submitted to any institution in partial or complete fulfilment of another degree.

N. (Victor) Z. Tadros

CONTENTS

Page

ILLUSTRATIONS

FIGURES

CHAPTER 3 : TECTONIC SETTING AND BASIN EVOLUTION Page

Page

CHAPTER 6 : GENETIC STRATIGRAPHIC ANALYSIS

Page

CHAPTER 7 : GENETIC FACIES ANALYSIS

Page

CHAPTER 8 : DEPOSITIONAL SETTING AND ITS INFLUENCE ON COAL DISTRIBUTION AND QUALITY OF THE UPPER BLACK JACK DEPOSITIONAL SEQUENCE

PHOTOS

CHAPTER 1: INTRODUCTION

CHAPTER 4: STRUCTURAL ELEMENTS

CHAPTER 7: GENETIC FACIES ANALYSIS

TABLES

APPENDICES

SUPPORTING PUBLICATIONS

1. TADROS N.Z. 1982. Geology and coal resources west of Boggabri. *Geological Survey of New South Wales, Quarterly Notes* **48**, 2-14.

2. TADROS N.Z. 1985. Geology, depositional environments, and coal resources of the Breeza area. *Geological Survey of New South Wales, Quarterly Notes* **59**, 1-18.

3. TADROS N.Z. 1986a. Lacustrine facies — upper Black Jack Formation — Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes* **62**, 31.

4. TADROS N.Z. 1986b. Sedimentary and tectonic evolution, upper Black Jack Formation, Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes* **65**, 20-34.

5. TADROS N.Z. 1988a. Depositional controls on coal quality of the Hoskissons Coal Member, Black Jack Formation, Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes* **70**, 1-14.

6. TADROS N.Z. 1988b. Maceral composition: variations and significance to the formation of the Hoskissons Coal Member, Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes* **71**, 1-18.

7. TADROS N.Z. 1988c. Structural subdivision of the Gunnedah Basin. *Geological Survey of New South Wales, Quarterly Notes* **73**, 1-20.

8. TADROS N.Z. 1993a. Review of the stratigraphy of the Gunnedah Basin. *Advances in the Study of the Sydney Basin, 27th Symposium, Department of Geology, University of Newcastle, Proceedings* 39-49.

9. **TADROS N.Z. 1993b. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* Geology 12, 649 pp.**

10. TADROS N.Z. 1995a. Sydney - Gunnedah Basin overview. *In* Ward, C.R., Harrington, H.J., Mallett, C.W. & Beeston, J.W. (Editors): Geology of Australian coal basins. *Geological Society of Australia Coal Geology Group Special Publication,* 1, 163-175.

11. TADROS N.Z. 1995b. Gunnedah Basin. *In* Ward, C.R., Harrington, H.J., Mallett, C.W. & Beeston, J.W. (Editors): Geology of Australian coal basins. *Geological Society of Australia Coal Geology Group Special Publication,* 1, 247-298.

12. TADROS N.Z., WHITEHOUSE J. & MOFFITT R.S. 1987b. Geology and coal resources of the Narrabri area. *Geological Survey of New South Wales, Quarterly Notes* **68**, 1-18.

13. TADROS N.Z. & HAMILTON D.S. 1991. Utility of coal seams as sequence boundaries in the non-marine upper Black Jack Formation, Gunnedah Basin. *Advances in the Study of the Sydney Basin, 25th Symposium, Department of Geology, University of Newcastle, Proceedings,* 128-137.

14. HAMILTON D.S. & **TADROS N.Z.** 1994. Utility of coal seams as genetic stratigraphic sequence boundaries in non-marine basins: an example from the Gunnedah basin. *American Association for Petroleum Geologists Bulletin* , **78**, No. 2, 267-286.

PAPERS PUBLISHED IN THE GUNNEDAH BASIN MEMOIR (TADROS 1993b)

TADROS N.Z. 1993c. Introductory notes. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 3-12

TADROS N.Z. 1993d. History. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 3-12

TADROS N.Z. 1993e.Tectonic evolution. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 47-54.

TADROS N.Z.. 1993f. Structural elements. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 55-86.

TADROS N.Z. 1993g.Influence of structural elements on the basin fill. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 87-92.

TADROS N.Z. 1993h.Lithostratigraphy. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 95-134.

TADROS N.Z. 1993i. Upper Black Jack depositional episode. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 245-296.

TADROS N.Z. 1993j. Petrographic composition and environment of formation of the Hoskissons Coal Member. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 427-438.

TADROS N.Z. 1993k. Coal resources of the Gunnedah Basin overview. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 441-444

TADROS N.Z. 1993l. Breeza area. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 492-501.

TADROS N.Z. 1993m. Narrabri area. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 511-522.

TADROS N.Z. & HAMILTON D.S. 1993a. Introductory notes on sedimentology. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 167-168.

TADROS N.Z. & HAMILTON D.S. 1993b. Distribution, quality and utilisation potential of the main coal seams of the Mullaley Sub-basin. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 445-484.

TADROS N.Z. & HAMILTON D.S. & WHITEHOUSE J. 1993. Coal resources of the Mullaley Sub-basin. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 485-522.

TADROS N.Z., MCDONALD S.J. & SKILLBECK C.G. 1993. Watermark Formation. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12,** 104-105.

HAMILTON D.S., **TADROS N.Z.** & THOMSON S. 1993. Depositional setting and its influence on the Permian coals. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12**, 389-425.

MCDONALD S.J., SKILBECK C.G. & **TADROS N.Z.** 1993. Porcupine Formation. *In* Tadros N.Z. ed. The Gunnedah Basin, New South Wales. *Geological Survey of New South Wales Memoir* **Geology 12**, 103-104.